City Water Resilience Approach: A five-step methodology to build water resilience at an urban scale

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ABSTRACT
The concept of resilience is becoming a new paradigm for urban planning in the face of water crises. This has accelerated the need for innovative approaches and tools that can guide cities to develop and implement resilience concepts by promoting action-oriented decision making. This paper presents a methodology, the City Water Resilience Approach (CWRA), which enables cities to build water resilience at an urban scale.

Through this approach, cities are able to take a holistic and collaborative approach to develop water resilience strategies guided by a detailed step-by-step methodology. The transition pathway from one step to the other is facilitated by a set of tools and resources that help city stakeholders to implement this method. The steps include understanding the urban water system and mapping the key stakeholders, assessing the current resilience capacity using the City Water Resilience Framework (CWRF), collaboratively developing and implementing urban water resilience action plan, and monitoring and evaluating the results of the interventions. What makes CWRA an innovative approach and unique from other resilience methodologies and tools is that it features water governance as an entry point to build resilience, which is a key component embedded in the CWRA tools and activities. In addition to this, CWRA is a co-created process together with cities, making it cohesive and globally applicable. The CWRA tools have been piloted in the city of Cape Town and Greater Miami and the Beaches (GM&B)\textsuperscript{iv}.

1. INTRODUCTION
Cities globally are facing water crises. By 2030, natural disasters could cost cities up to USD 314 billion annually, pushing almost 77 million urban residents into poverty (World Bank, 2015). Amongst these disasters, water-related hazards (e.g. flood risk, drought, storm surge, and sea-level rise) account for nearly 90% (World Water Assessment Programme, 2012). Expanding urbanization, which is estimated to result in 2.5 billion more people living in cities and towns by 2050 (UN-HABITAT, 2019), and the risk of such disasters continue to increase, has put enormous pressure on urban water systems and its governance.

Over the past few decades, the concept of resilience has gained momentum as a smart planning model to manage urban resources and combat urban crises of different nature. However, even though this concept has received good coverage in theoretical studies, works on resilience practices are rare and remain elusive, particularly for the water sector. Because of its multidisciplinary origin and limited pieces of evidence around its operationalization, practitioners and decision-makers alike find the practical applicability of resilience theories challenging (Johannessen & Wamsler, 2017; Meerow & Stults, 2016). Even within the resilience scholarship, the use of the terminology ‘water resilience’ is rare; the existing literature refers narrowly to the resilience of urban water systems (Johannessen & Wamsler, 2017; Leigh & Lee, 2019). Deriving inspiration from existing definitions on the term resilience (UNISDR, 2009) ‘water resilience’ could be conceptualized as “the capacity of
cities to function in the face of water-related stresses, so that those living and working within the city can survive and thrive” (CWRA, 2019b). Given the scale and complexity of the natural disasters impacting urban water systems, understanding and measuring such a complicated concept is not easy. Moreover, there are very few rigorous approaches that are currently available that can help cities facilitate this process of building water resilience (CWRA, 2019b).

Against this backdrop, this paper introduces the City Water Resilience Approach (CWRA), a new and innovative approach to urban water management. It is a methodology that emerges as a new model of urban water management which will help cities to collaborative build resilience actions to local water challenges through improved water governance. Through step-by-step guidance combined with a set of tools and resources, CWRA enables cities to make better urban water planning and investment decisions. It defines five essential steps (Figure 1) that will help in the transition pathway from understanding urban water systems, identifying and engaging with key stakeholders (Step 1); to conduct a baseline assessment of the city’s current water resilience capacity through multi-stakeholder consultation (Step 2); to collaboratively defining, prioritizing, and water resilience action plans (Step 3); followed by implementing those actions (Step 4); and monitoring and evaluating results to reassess the priorities and inform future programmes and planning (Step 5) (CWRA, 2019b, 2020).

CWRA provides a mix of digital and analog tools, which includes the OurWater digital tool (used in Step 1) and the assessment tool City Water Resilience Framework (CWRF) (used in Step 2). The OurWater digital tool maps the city’s water system, key stakeholders involved in urban water management, and impacts of the shocks and stresses on the city’s water system. Understanding the urban water system and mapping its stakeholders is a fundamental step before conducting any diagnosis on the city’s resilience capacity. CWRF, an assessment tool, measures the city’s current water resilience capacity in an integrated way by considering four critical dimensions: Leadership and Strategy, Planning and Finance, Infrastructure and Ecosystems, Health and Wellbeing. In this way, CWRF assesses governance as a key element of water resource management and service provision.

This paper first describes the methodology used to develop the five-step approach of CWRA and the two associated tools. In the results sections, the paper discusses what each of these five
steps entails, with examples from the practical implementation of the approach in two case studies, namely the city of Cape Town and Greater Miami and the Beaches (GM&B).

2. METHODOLOGY

The development of the five-step approach and the tools was informed by extensive desk research, review of international best practices, consultation with subject matter experts, and direct engagement with cities through site visits, workshops, Focus Group Discussions (FGD), and Key Informant Interviews (KIIs). The development phase of CWRA took place between 2018-2019, and a version of the CWRA was piloted in 2019. The methodology is summarized in Table 1 and briefly discussed below.

Table 1. Methodology to develop CWRA and its tools

<table>
<thead>
<tr>
<th>Method &amp; activities</th>
<th>Periods</th>
<th>OurWater digital tool</th>
<th>City Water Resilience Framework-CWRF</th>
<th>The wider CWRA five-step process</th>
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<tbody>
<tr>
<td><strong>Desktop Study</strong></td>
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<tr>
<td>Literature review on existing resilience and water related tools and approaches</td>
<td>2018</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Literature review on governance and water resilience</td>
<td>2018 (May-July)</td>
<td></td>
<td>X</td>
<td></td>
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<tr>
<td>Literature review on best practices on resilience indicators</td>
<td>2018</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>Literature review on different methodologies that help transition from assessment to action planning.</td>
<td>2019 (June-August)</td>
<td></td>
<td>X</td>
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<tr>
<td><strong>Engagement with cities</strong></td>
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<td>Direct engagement with city stakeholders (public, private, and civil society) from five cities (Amman, Cape Town, Hull, Mexico City, and Greater Miami and the Beaches-GM&amp;B) through site visit, workshops, interviews</td>
<td>2018-19</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Three additional cities -Rotterdam, Thessaloniki, Greater Manchester - were engaged remotely.</td>
<td>2018-19</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td><strong>Data Analysis</strong></td>
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<td>The data collected from deskwork and field visits were processed and analyzed, using a joint emergent and a priori coding technique of analysis. 1577 factors were identified, which were assessed, aggregated and a set of water resilience sub-goals and goals identified. The results also informed the refinement of the four dimensions.</td>
<td>2019</td>
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<tr>
<td><strong>Expert consultation, Validation and Piloting</strong></td>
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<td>Consultation meetings throughout the development process among CWRA team (Arup and SiWI) were conducted through regular online meetings and a face-to-face workshop held in London in August 2018.</td>
<td>2018-19</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Consultation with digital experts (We are Telescopic, London) through regular online meetings and a face-to-face workshop held in London in August 2018.</td>
<td>2018-19</td>
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<tr>
<td>Global Knowledge Exchange (GKE) validation workshop held in London gathered city stakeholders and global experts.</td>
<td>2018 (21-23 August)</td>
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<tr>
<td>Testing and Piloting in City of Cape Town and GM&amp;B through a multi-stakeholder workshop.</td>
<td>2019 (June-July)</td>
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2.1. Literature Reviews: The literature reviews identified demand for a methodology to guide decision-making and implementation of water resilience activities in cities. To develop such a methodology and tool, a series of literature reviews were conducted. First, literatures on assessing
resilience of cities or water systems were reviewed, which included set of frameworks that refers to concepts used to assess, approaches for carrying out the activities, and associated tools. In this review, eight approaches, nine frameworks, and 14 tools designed to assess resilience in the context of cities and/or water systems were reviewed. Second, nearly 50 academic sources were reviewed to understand the commonly applied practices and qualities that help build water resilience. Third, 40 sources were reviewed to understand common shocks and stresses related to water (CWRA, 2019b). Fourth, a review of the literature on water governance identified key enabling factors for building resilience (Djalante et al., 2011, 2013; Folke, 2006; Johannessen & Wamsler, 2017; Lebel et al., 2006). Sixty articles were reviewed in this governance and water resilience study, using keyword searches in Open access journals in JSTOR, MDPI Sustainability journal, Ecology, and Society journal, Taylor and Francis Online (CWRA, 2019a). The literature review also identified a need for new tools to facilitate the CWRA process generally, and to support water governance in particular. The four dimensions of the CWRF assessment framework drew inspiration from the reviewed frameworks, including the City Resilience Index (CRI, 2014), and incorporated elements related to water governance that were identified through the review of the governance literature. The literature review also identified the different categories of shocks and stresses to include within the OurWater digital tool. Finally a review of specific methodologies that help the transition from assessment to action planning was conducted, which informed strengthening the steps from water resilience assessment (Step 2) to action planning (Step 3).

2.2. Engagement with cities: To fill the gaps identified in the literature review and for practical application of the conceptual approach and tools, a fieldwork strategy was planned for direct engagement with cities (Table 2). Five partner cities were selected that represent diverse geographies, facing persistent and a range of water related shocks or stresses, and represents different governance systems. Three additional cities were engaged remotely for feedback on the tools developed (Table 1). The governance workshops in cities validated the need for a governance tool—first identified through the literature review—that could help inform decision-making processes by mapping water systems, stakeholders and projects. In some cities, early versions of the OurWater tool were presented to stakeholders for feedback. Additionally, the direct engagement with cities helped the CWRA team to gather relevant evidence, validate and refine the early framing of the assessment framework-CWRF. Feedback received during these workshops informed ongoing development the wider five-step methodology.

2.3. Data analysis: The data collected were collated in a master database to identify the factors of resilience. These were then were analyzed using a coding methodology that helped aggregate the different factors into positive factors or negative factors in addressing the city’s water-related shocks and stresses. These factors were grouped into themes that are termed as water
resilience sub-goals. Sub-goals were further aggregated into larger groups of goals that represent families such as ‘collaborative governance’ and ‘sustainable funding’ and were assigned to the related dimensions (Bruce et al., 2020). Based on these results a draft version of CWRF was developed and later validated in a multi-stakeholder workshop, which informed the practical applicability of the framework, identification of irrelevant sub-goals or goals, rearrangements, and suggested clarifications to the language where applicable. Separately, a review of academic and grey literature on the topic of indicators, indices, and resilience measurement and field experiences helped identify both the method to selecting indicators, and the indicators themselves.

2.4. Expert consultation, validation, and piloting: The development of the steps and tools included consultation with subject matter experts from Arup, the Stockholm International Water Institute (SIWI), The Resilience Shift, and 100 Resilient Cities (100RC) through virtual and face-to-face workshops. A validation workshop was held at the Global Knowledge Exchange (GKE) gathering city stakeholders along with experts from other global organizations like World Bank, 100RC, The Resilience Shift, OECD, World Economic Forum, and Alliance for Global Water Adaptation. The early versions of the tools were presented at the workshop where participants provided feedback. Following the validation workshop, the tools were improved and piloted in two cities- Cape Town and GM&B through multi-stakeholder workshops. The workshop included presentation and feedback on the wider CWRA process, which helped identify gaps and strengthen the five-steps, particularly related to the assessment (Step 2) and developing an action plan (Step 3).

3. RESULTS

The CWRA research indicates that although there are a number of resilience assessment frameworks and tools to measure a city’s performance and resilience capacity, but guidance on how to define and improve decision-making around urban water resilience is limited (CWRA, 2019a, 2019b). CWRA addresses this demand by proposing a method that is designed in such a way that helps cities move beyond the assessment phase to defining water resilience actions, prioritization, implementation, and monitoring, and evaluating the results of interventions. This process of building resilience is illustrated in the five steps of the approach (Figure 1) as discussed below in detail.

3.1. Understanding the Urban Water System and engaging with all relevant stakeholders

The first step of the CWRA process is establishing a City Resilience Champion. The Resilience Champion is a local stakeholder accountable for leading and owning the process in the city, and for promoting its implementation through its convening power and influence (CWRA, 2019b). As a foundational step to build resilience, the champions must first develop an understanding of the urban water system and the institutional landscape governing the system, which will set the ground to define a clear objective and common vision to build a holistic water resilience strategy.

However, the findings from the CWRA research shows that a holistic system and stakeholder mapping is not always easy (CWRA, 2019b). Urban water systems are complex, having interdependencies with other urban sectors (e.g. transport, energy, food supply), conflicting interests and priorities. The decision taken in other sectors may impact the water sector, and vice versa. Additionally, there are often spatial misalignments between the administrative boundaries of the urban water sector and the wider basin and natural water systems within which the city sits. Even within the urban water sector there may be fragmented institutional arrangements and multiple actors involved in urban water services. Therefore clarity on ‘who does what, at what level, and how’ will help identify these gaps and mismatch.

Under these complexities, cities need innovative tools that can guide them in the process of developing an integrated and inclusive urban water resilience strategy, through coordinated action among multiple stakeholders. Towards this, the OurWater tool is designed as an easily
understandable tool for non-technical users, guiding to understand the complex interactions of the urban water system through visual system diagrams (The Resilience Shift, 2019). Although the tool is designed specifically with the first step of the process in mind, it can also be applied independently from the CWRA. OurWater consists of four key components:

i. **Interactive water cycle diagrams**: It helps users map and visualize the local water system, showing links between different natural and man-made infrastructures (assets) such as water sources, drainage systems, dams, and reservoirs. Figure 2 shows an example of a water system map of Cape Town. Each asset is tagged with information on the stakeholders responsible for the assets and their respective roles (e.g. manager, operator, financier, user group, regulator) and the potential impacts of various shock or stress (e.g. flood, droughts, earthquake, groundwater depletion) on the asset.

![Figure 2 Water cycle diagram of City of Cape Town, available at https://app.ourwater.city/cape-town/water-cycle](https://app.ourwater.city/cape-town/water-cycle)

ii. **Stakeholders**: Based on the mapping of stakeholder’s roles to a particular asset, a stakeholder connection diagram can be built in the digital tool to illustrate the connection between different stakeholders within the system (Figure 3). This helps in understanding the need to strengthen coordination between the connected stakeholders, for the general management of the asset, and to coordinate management when the asset is affected by any shock or stress.
iii. **Mapping of programmes and projects**: This function collates information on different water projects and programmes, and describes the roles and responsibilities of different stakeholders in implementing programmes and projects. This information helps understand the gaps in the existing programmes and in prioritizing different water resilience action plans developed using the CWRA methodology. For example, if a city government agency has developed an urban resilience strategy, then city stakeholders, while defining the CWRA water resilience action plans, can prioritize actions and propose water resilience activities to strengthen the existing strategy.

iv. **Governance**: This function identifies the different roles of stakeholders across core water governance functions: Planning and Preparedness, Policy and Strategy, Financing, Regulation, Coordination, Monitoring and Evaluation, Capacity Development. These describe the key roles performed within the water sector, in various forms and to varying extents and quality, for the organized development and management of water resources and services (Jiménez et al., 2020). Users can identify the gaps where no organizations are fulfilling any particular role within the functions, or if there is an overlap in the roles (The Resilience Shift, 2019).

In Cape Town and GM&B OurWater was used to show the interlinkages between main water sources such as freshwater sources, aquifers, dams, connecting to the water treatment plants, potable distribution points, users, sewage systems. The tool identified misalignment between various regional, national and city decision-makers and the impacts these have on water supply. Understanding these linkages and identifying opportunities for improving collaboration between these closely connected stakeholders across municipal, regional and national spheres of government in defining the city’s water resilience strategies (Figure 3) was shown to be critical for ensuring the water sustainability in both cities.

### 3.2. Assessing City Water Resilience capacity
Assessing what elements are hindering resilience in the water sector is a critical step for applying resilience thinking into planning strategies (Sellberg et al., 2018). Towards this, the second step of the CWRA process focuses on assessment. This step is facilitated using the City Water Resilience Framework (CWRF), which helps structure cities’ thinking and prioritization around water resilience, including identifying what elements are hindering resilience, and what is required in building resilience. CWRF has been developed as a holistic, comprehensive, and technically robust framework to assess urban water resilience and inform urban water resilience action planning, by addressing water governance gaps. The framework is structured as a wheel (Figure 4), with three rings, which consist of dimensions, goals, sub-goals and indicators (CWRA, 2020). The innermost ring of the framework comprises of four dimensions, which are the critical areas for an urban water system to build resilience. These are Leadership and Strategy, Planning and Finance, Infrastructure and Ecosystems, and Health and Well-being. Through these dimensions, CWRF outlines a holistic approach to managing urban water resources and services, by connecting environmental, human, societal, infrastructural, and governance elements of the urban water system. These dimensions help organize the resilience assessment, and guide future action (CWRA, 2019b, 2020).

The second layer of the wheel consists of resilience goals, which indicate what needs to be achieved in the dimensions in order to realize a resilient water system. Next to the goals is the third ring which represents the sub-goals. The sub-goals are the critical factors needed for realizing each goal. These sub-goals are accompanied by specific and measurable qualitative and quantitative indicators. The qualitative and quantitative indicators allow cities to measure and score the resilience performance of the water sector at an urban scale across these four dimensions. Indicators are not illustrated in the CWRF wheel diagram.

The CWRF is implemented through a multi-stakeholder Assessment Workshop, where city stakeholders, through in-depth discussions, score the indicators, guided by a set of guiding criteria for each of the qualitative indicators and identify the existing resilience gaps (CWRA, 2020).

The Resilience Champion is responsible for the planning these Assessment Workshop to ensure the workshops includes a diverse group of knowledgeable and informed stakeholders. The Assessment Workshops were conducted in Cape Town and GM&B through two-day sessions where participants scored indicators for all sub-goals. Through this exercise, participants identified strengths and weaknesses in the respective city’s approach to water management, and prioritized challenges and resilience gaps to address.

3.3. From Water Resilience Assessment to Actions
The last three steps of CWRA focus on the need to move beyond assessment, whereby the city stakeholders translate the assessment results into actionable initiatives, implement these interventions, and monitor and evaluate the results of the interventions. These steps are Co-developing and Prioritizing Water Resilience Action Plan (Step 3), Action Plan Implementation (Step 4), and Evaluating, Learning, and Adapting (Step 5).

i. **Visioning workshop to co-develop and prioritize water resilience action plan:** Based on the gaps and problems identified during the Assessment Workshop, city stakeholders are able to define solutions and potential activities to address those gaps. Towards this, a multi-stakeholder workshop is conducted after the Assessment Workshop. This workshop is defined in the CWRA process as the visioning workshop. In this workshop, design sprint exercises are undertaken to analyze the problems and gaps, followed by identifying the root causes, the opportunities, and interventions that will help address those gaps (Figure 5). The analysis of root causes helps to identify the underlying sources of the problem, including social, environmental, political and governance, financial, technological considerations (CWRA, 2020).

The participants, through in-depth discussions and dialogue, propose actionable activities/interventions. These include estimated cost, timeline, responsible organization, existing assets, and resources, for each of the activities. For instance, during the GM&B Assessment Workshop, stakeholders identified as a knowledge-sharing between government agencies as a key challenge. Through the visioning workshop, stakeholders proposed an ‘Accessible Knowledge-Action Platform: The One Water Platform’—which will generate and share knowledge around water management, disaster preparedness and recovery, blue-green infrastructure and other issues that impact the water resilience of GM&B (The Resilience Shift, 2020b).

The CWRA process emphasizes that the proposed action plans must be built on existing short, medium, and long-term programmes and projects (e.g. city water master plan, sector planning, disaster management plans, etc.). This helps ensure there are no overlaps, and that the proposed actions help in strengthening the existing programmes, identifying responsible actors, and securing resources under the existing projects. For instance, the initial identification of the GM&B’s Resilience 305 strategy for the city, helped city stakeholders at the visioning workshop to prioritize water resilience actions that could inform strengthening the water components of the 305 strategy. The OurWater digital tool supports this objective.

ii. **Implementation and evaluation strategy:** To continue with the process and successfully implement the prioritized action plan, the city stakeholders should collectively agree on committing towards implementing the action plan, and city political leaders and local authorities should endorse the action plan. In addition to this, the city stakeholders must also consider aligning the action plan with the sector’s annual report, which is discussed in regular joint ministerial review meetings. Broad coordination and agreement between
authorities will ensure the action plan aligns with the sub-national and national level plans and priorities, open opportunities to acquire resources and help facilitate the water resilience discussion around the broader sectoral issues and across different levels. The Resilience Champion will also be responsible for monitoring and engaging with the stakeholders to ensure that implementation results and evaluation reports are shared on a regular basis and that the ongoing activities reflect the resilience value. Another important element in the CWRA process is evaluating, learning, and adapting, which is a key driving factor in the process of building resilience. CWRA Step 5 follows up on implementation, focusing on monitoring and evaluation of the intervention results at regular intervals to ensure that the plan progresses to meet the resilience goals. This step highlights the need to monitor and address associated risks and challenges in a timely manner, to re-assess objectives and priorities, and conduct a follow-on assessment in 2-3 years that evaluates progress against the baseline.

4. Conclusions

The CWRA process and the tools have been developed through a co-creation process, with direct contribution from cities. Engagement with cities provided practical insights to improve the conceptual tools and the five-step methodology. In reference to the CWRF framework, it helped to identify relevant sub-goals or goals, rearrange the location of sub-goals, and suggest clarifications to the language to make the framework practical and relevant to globally applicable. New indicators were developed based on the learnings from the Cape Town Assessment Workshop, which emphasised the need to assess the assets management and protection of the natural environment. In addition, the application of the tools and approach enabled cities to strengthen their existing strategies; for instance, the piloting of CWRF in GM&B largely contributed to strengthening GM&B's Resilient305 Strategy (The Resilience Shift, 2020b) and for Cape Town, the city stakeholders acknowledged that the CWRF results could be used in the implementation plan of the newly launched Water Strategy of the city (City of Cape Town, 2020; The Resilience Shift, 2020a). These processes also helped in identifying the challenges around financial constraints cities may face in the implementation of the action prioritized and capacity gaps among stakeholders to implement the actions and continue with the CWRA process. Another challenge noted was capturing community perspective, as relatively few community representatives were able to attend the workshops as these were held during working hours.

Based on the learnings from these implementations, CWRA methodology will further be refined and applied in other cities. Future development will focus on how CWRA can be successfully applied to cities in low-income countries, given that nearly 90% of urban growth will occur in less developed regions, where capacity and resources are most constrained and development challenges most intense (UN-HABITAT, 2019). In these areas, the application of holistic and innovative tools will be especially valuable.

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References


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